The Biological Significance of Selective Adsorption.

BY JEAN DUFRENOY.

Modern biologists come more and more to view living matter in the light of colloid complexes, of which those constituting nucleo and cytoplasma may be termed "cyto-colloids," whereas those building cell-walls or intercellular spaces may be named "histo-colloids."

Adsorption is a most important property of colloids. Adsorption indeed, is most satisfactorily explained as a concentration of a solute at a surface, and colloids offer much useful surface.

Certain surfaces not only have the power of adsorbing a solute as a whole from solution, but have the power of adsorbing a part of a solute at a greater rate than the other.

That an ion may be thus selectively adsorbed from an electrolyte, concomitant or previous hydrolysis of the electrolyte is of course necessary.

Living matter being collöidal, is possessing selective adsorbing properties, which may tentatively furnish an explanation of the metabolic processes in the living being, and of the migration of solutes into the cells, or of the color reaction of the tissues.

A most convenient biocolloid to experiment on, was furnished to us by the mucous deposits in the thermal springs of Barèges (Pyrénées). These deposits long known as "Barégine" are zooglæ secreted by various Bacteriacea. True Baregine, as defined by us, is a furfuroïd, soluble in xanthogenate reagents, as distinguished from the cell wall proper of the Bacteria, which is made up of nonsoluble chitin-like material. [8, 11.]

1.—Basophilous Adsorption.

Many vegetable histo-colloids have a superior adsorbent capacity for bases, and redden blue litmus, (which is a salt, containing a strong base, while the acid is the red dye itself.)

This reddening is easily observed in the case of Barégine by the following experiments: (1.) Blue litmus which is made to filter through a plug of Barégine, first filters red, and later on filters uncolored. (2) Blue litmus, kept in a glass tube above a plug of Barégine, reddens, and in a few hours loses its color from its

contact to the Barégine upwards. In both cases, adsorption is selective at first, and total ultimately.

2.—CONSEQUENCES OF BASOPHILOUS ADSORPTION.

There is a struggle for bases constantly going on between basophilous colloids in the plant and those in the habitat. This is most conveniently studied in the cases of unicellular plants: Iron-bacteria, Diatoms, but it is as important for flowering plants in the field. But even the different parts of the same plants struggle for bases, and this should be studied first.

1.—METACHROMASIA.

Many blue dyes are salts, containing colored base and acid radicals. Either the base or the acid, when free, may be itself a red dye.

Whenever basophilous substances are in contact with these blue salts containing a red free base, they color red, by adsorbing the red base.

The red color displayed by colloids bathing in blue solutions is termed metachromatic.

Therefore, most cases[1] of metachromasia readily explain by selective adsorption, and we actually observed substances which color metachromatically to be basophilous: For instance, such zooglæ in the Barégine, which adsorb Fe or Cu as bases from their salts, also color red by basic blues (Naphtylen blue, Methylen blue.)

The same explanation no doubt holds for cyto-colloids; and the so called "metachromatic granules" in the cells certainly are basophilous gels (or maybe sols). Indeed, metachromatic granules were artificially produced, where metachromasia is the result of selective basophilous adsorption: A drop of a xanthogenate (obtained by dissolving Barégine into CS_2+KOH mixture) being placed in contact with a drop of aqueous solution of naphtylen blue or Polychrome blue, it appears an emulsion of tiny red granules, exactly alike the metachromatic granules in the cells.

Metachromatic granules are conspicuous substances in the cell,

[1] Some cases may result of different colors displayed by the same solute as its solvent changes, as assumed by Moreau.[2] In fact, we found the "insoluble blue acid of the Congo, to yield a red solution in Amylic alcohol.

[2] F. MOREAU, Sur les phéno. de métachromasie: *Bull. Soc. bot. France*, t. 63, p. 72, 1916.

but their significance is still doubtful. They have been demonstrated by Guilliermond and Moreau [15, 19] to be secreted by mitochondria, and, in that respect, it is to be noted that in the Sulfuro-bacteriacea such as *Thiothrix sp.*, free sulfur, in the form of intra-cellular globules, deposits only in contact of or inside of metachromatic granules.

Other substances, such as oxalate of potassium, were often found in cells the content of which had degenerated into a basophilous substance, and the relations of basophilous biccolloids to salts in the cell, demand further investigation. That it may be of biological interest appears from the fact that, while nucleo-chromatine is acidophilous in healthy cells, it shows marked basophily in tumour cells of Pines. [8]

This change may result from an altered proportion between base-adsorbent and acid-adsorbent nucleo compounds, or it may be that bases becoming deficient, the base-requirement of the acid nucleo-compounds is no more satisfied.

2.—Struggle for Bases from Host to Parasite.

Marked basophily is often observed in diseased tissues, due to development of much pectic material. [6]

Basophily is conspicuous in the wood of trees, where it is infected by mistletoe. Which wood was found by Councler to be deficient in Ca, but to be rich in PO_4H_3 and K_2O. Basophilous degenerescence may offer to the parasitized tissue a way to oppose the migration of bases from host to parasite.

3.—Iron Deposing Bacteria.

Adsorption again plays an important rôle in the depositing of iron ore by "iron bacteria."

The phenomena is easily studied in the hottest thermal springs of Barèges ($t^\circ = 42^\circ.8$ cent.) where *Ferro-coccus* were observed at various stages of development.

At first they are free, isolated or actively-dividing, highly refringent and thin-walled globules, imbedded in a basophilous zooglæ. Later on, they crowd as *Staphylo-coccus*, their walls thicken and become impregnated with Iron, (easily precipitated blue by Hydrochloric ferrocyanide or red by Sulfocyanide of Potassium.)

The older *Staphyloccus* ultimately form a thin rusty crust, of

which the iron is no more soluble, or at least is not more interchangeable with other bases such as Cu.

Although biochemical reactions may be efficient in changing the soluble iron salts from the thermal water, into the non-soluble iron hydroxide, the adsorbing effect of the cell walls plays a great rôle: in fact, Fe or Cu ions may be fixed in a few minutes by Barégine, and those parts which fix the metal most energically are also those which show the greatest basophily.

It seems therefore that Fe ions are at first adsorbed from the solutions and then biochemically oxydized.

4. Diatoms.

Building of siliceous skeletons by Diatoms was compared by Cohn to depositing of iron by Iron-bacteria.

Indeed, we found that *Synedra affinis*, growing in the Bassin d'Arcachon, near to rusting iron pieces, had developed a rusty color. Moreover, we were able to grow rusty Diatoms in very weak solutions of Iron sulphates in sea water. These rusty Diatoms yielded Prussian Blue, by treatment with hydrochloride ferrocyanide.

Here again we may turn to adsorption for an explanation; Diatoms possess, inside of their siliceous skeleton, a very thin pectic wall, which may adsorb metallic ions, and which we made even to adsorb Cu.

5.—Struggle for Bases from Soil to Plant.

Most plants are in contact with the soil through the basophilous pectic walls of their root-hairs.

These walls compete for bases with the basophilous compounds in the soil.

Bases may be in excess in soils and then easily obtainable by plants, or they may be strongly fixed by the basophilous complex in the soil, such as humic acids, iron hydorxyde . . . the soil being then termed "acid." Most plants thrive on the former soils, but there are few able to live on "acid soils." The former plants have been demonstrated to possess but feeble adsorbent power towards Ca ions, while the latter have a high competing power for bases. [17.]

3.—Acidophilous Adsorption.

Some colloids, such as the basic gels: oxides of Z, Th, Al, La, Zn, Be, Fe and Cr, or celluloses, adsorb the acid more quickly

than the base from dissolved salts. Cellulose is widely distributed in vegetable cell walls, where it is associated to pectic acid. Most cell walls therefore may adsorb basic colors by their pectic membrane, and acid dyes by their cellulos constituents.

Adsorption of acid dyes, such as Congo red, Eosine, Fuchsin . . . is conspicuous in the cell-walls of Sulfuro-bacteriacea, *Thiothrix*. . . . It is even so strong, that a small quantity of *Thiothrix* placed in a solution entirely loses color.

Acidophilous basic gels being widely distributed in the habitat and in histological tissues, may exert an adsorbent effect on the acid ions in the cell, which effect demands investigation.

4. Reactions Accompanying Adsorption.

Thermal waters from Barèges' springs redden blue Congo by warming.

This may be accounted for by supposing that basic gels exist in the thermal waters, which adsorb the acid of Congo red at ordinary temperature, without change in the color, which remains blue; on warming, chemical reaction takes place and a salt of Congo red is formed, a red color appearing. At the same time, an insoluble blue acid of the Congo is precipitated, which may again yield interesting adsorbent effect.

Such reactions have called for the attention of numerous investigators and Wedekind and Rheinboldt conclude that adsorption effect may often precede chemical union, which seems specially true of biochemical reaction as was observed for iron depositing bacteria.

Summary.

1. The compounds, in living cells or tissues, are colloids displaying selective adsorption effect.

The constituents of cell walls and most granules in the cytoplasm are base-adsorbent colloids; they compete for bases, each with the other, and with the basophilous colloids in the habitat.

The constituents of nucleoplasma are generally acid-adsorbent, but may become base adsorbent in diseased cells.

Cellulose, an acid-adsorbent colloid, is widely distributed in plant cells and may exert powerful adsorption towards acids.

2. Adsorption effect may be preliminary to biochemical reaction, as is probably the case for iron depositing bacteria.

3. Competition for bases may result in serious loss of bases in

the habitat, and considerable accumulation of bases in plant tissues.

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Sexual Dimorphism and Some of Its Correlations in the Shells of Certain Species of Najades.

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I.—INTRODUCTORY.

Before Ortmann's discovery that the sex of Najades could be readily learned from associated peculiarities of gill structure, (4, 5,), systematists had only general information—of the type later to be compared in this paper—from which to identify the sex of a mussel when glochidia were absent. Hazy, (2), and Israel, (3), were able to distinguish the sexes of certain European species by such characters as relative length, height, and inflation. Israel, particularly, found associated with sex, certain colors of the epidermis of the shell. The investigations of these latter writers extended only to 3 species, none of which are closely related to those dealt with in this paper, and their original work never seems to have been followed up. In addition there occur in the papers of American investigators from time to time, scattered references to the sexual dimorphism of certain species based on some morphological feature of the shell. Such, however, are either not concerned with the species we are interested in, or are already summarized by Simpson, (6), or Walker, (8), whose information later will be brought out.

II.—PROBLEM, METHOD, AND MATERIAL.

While pursuing another investigation on the comparative morphological characteristics of certain mussel shells inhabiting the Upper Ohio Drainage and their corresponding ones in Lake Erie, (1) the writer obtained data of the type indicated, which he